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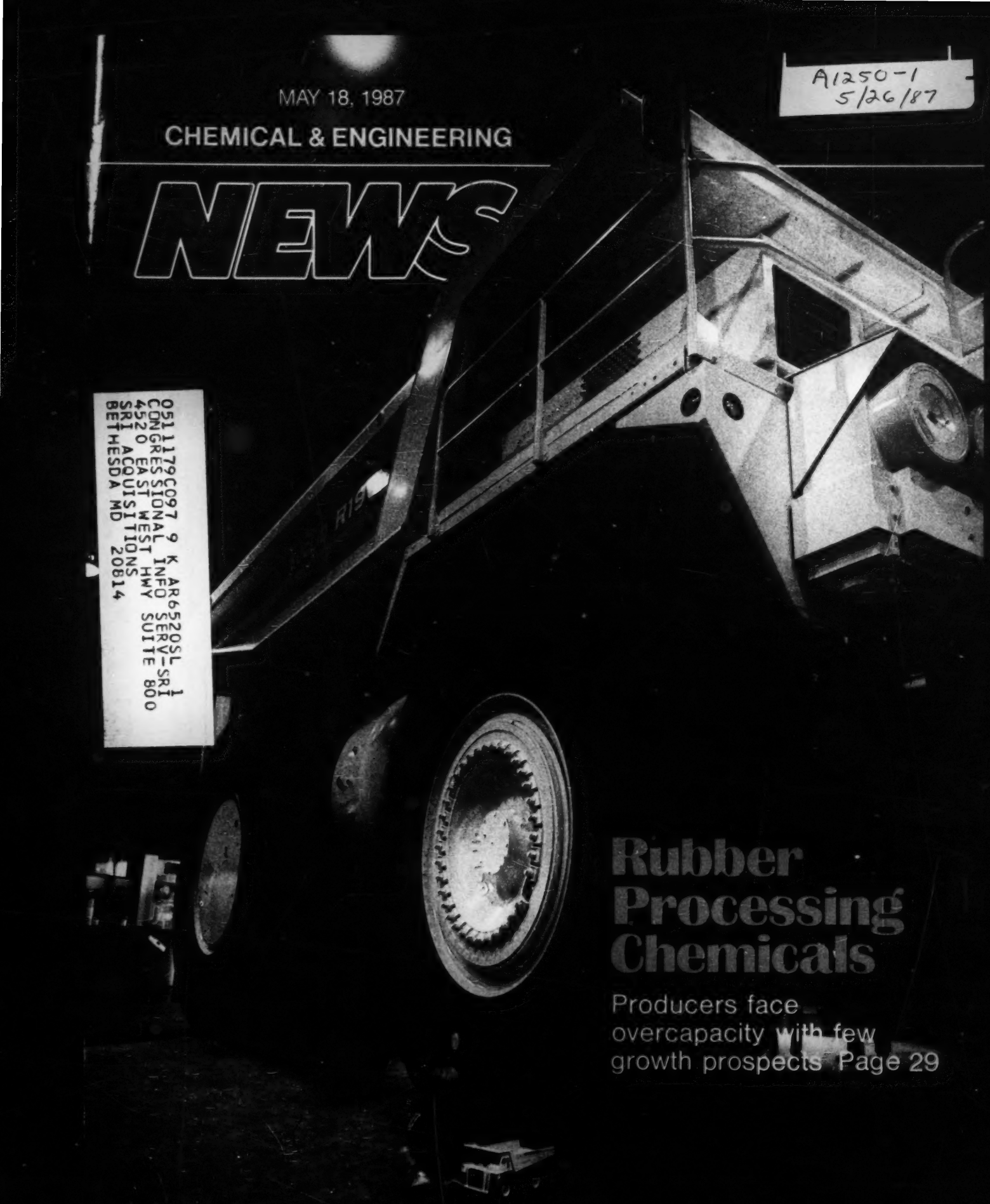

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Rubber Processing Chemicals

Producers face overcapacity with few growth prospects Page 29

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NEWS

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News of the Week

■ **Single-crystal thin film is key to measuring dramatically higher current-carrying capacity of high-temperature superconductors.** **Page 4**

■ **Two Italian firms, Montedison and EniChem, are continuing to discuss a possible merger, but the outcome remains unclear.** **Page 5**

■ **In Bhopal liability case, attorneys representing both India and Union Carbide tighten up strategies during discovery process.** **Page 5**

■ **Chemical engineering professor Harry Drickamer wins Welch award in recognition of his discovery of pressure tuning spectroscopy at very high temperatures.** **Page 5**

■ **Niagara Falls' mists may contain several toxic chemicals from the polluted river, according to Canadian groups probing the issue.** **Page 6**

Business

ICI Americas chairman Harry Corless, 1987 Palladium medalist, reflects on company's rapid growth in U.S.; market survey indicates slow worldwide growth for ethylene oxide and ethylene glycol; petrochemical industry outlook remains good as high operating rates continue. **Page 13**

Government

Academic labs face compliance with right-to-know regulations dealing with possession or spills of hazardous chemicals. **Page 19**

Technology

Natural gas producers aim at bigger share of electric power generation market; two new enzymes exhibit high thermostability, produce cyclodextrins from starch. **Page 22**

Science

Secret of an arctic moth that tolerates winter temperatures of −70 °C or lower may be its production of glycerol. **Page 28**

Books

The history of U.S. research in organic chemistry is traced in a series of comprehensive essays. **Page 50**

ACS News

Committee on Professional Training reports on 1986 bachelor, master, and Ph.D. graduates of ACS-approved schools; Indiana continues to be top producer of B.S. chemists. **Page 59**

Cover: Photo courtesy of Goodyear

Letters 2

Concentrates
Business 7
Government 18
Science/Technology 21

The Departments
New Products 54
ACS Comment 58
Meetings 68
Newscripts 92

Product Report

The rubber-processing chemicals industry, which has suffered reduced markets in the past decade, faces modest growth at best for the rest of the 1980s. **Page 29**

Rubber-Processing Chemicals

Bruce F. Greek, C&EN Houston

Monsanto recently added to its rubber chemicals plant located east of St. Louis

The rubber-processing chemicals industry, oversupplied for a number of years, faces a growth outlook that's modest at best for the rest of this decade. By the early 1990s, production of the large number of chemicals required to fabricate rubber products likely will remain below output of the late 1970s. Nonetheless, the importance of this industry is difficult to overlook, considering the heavy dependence on it by transportation and many other types of human-oriented activity.

The commercially significant rubber-processing chemicals comprise about 125 different organic chemicals produced by about 20 large and small companies. Rubber-processing chemicals are only part of the large quantities of materials used to fabricate a host of rubber products. Other materials include inorganic chemicals, such as pigments and fillers; minerals, such as sulfur; metals; steel wire used in tire beads; oils; fibers of both organic and inorganic compounds; and other reinforcing materials, such as carbon black.

Rubber-processing chemicals differ from many other materials used in rubber goods manufacturing and might rightly be called the prima donnas of the business. They generally cost from two to a hundred times as much as the other materials. Relative to the quantities of rubber and other materials used in a fabricated product, they are consumed in tiny amounts but have a major and critical impact on the final product. Their chemical structures usually are complex, and consequently their manufacture often is difficult, requiring expensive equipment, batch operations, and a high degree of attention to plant operation and to quality control.

Output of rubber-processing chemicals in 1987 will about equal 1986 production of 260 million to 280 million lb. That level will be only slightly higher than 1985 production of 260.1 million lb, according to the U.S. International Trade Commission. A 1987 production level of only 265 million lb would be 33% or more less than production 10 years ago, when the total was 402 million lb.

The value of rubber-processing chemicals produced in the U.S. this year likely will total $375 million to $400 million, based on estimates of production. However, about a third of production reported to ITC is captive production. So the other two thirds will bring less than $300 million to producers as outside sales.

Sales values are increased, however, by the value of rubber-processing chemicals imported into the U.S. Data on imports, considered incomplete and inaccurate by some industry sources, likely will show that imports will be about 10% of U.S. production this year, which will add about $40 million to the total sales volume. Sales figures include exports that are forecast to hold at about an eighth of production, or about 40 million lb.

CIRCLE 61 ON READER SERVICE CARD

Foreign trade in rubber-processing chemicals is not constant. Many factors influence it. The strength of the dollar before 1987 is an example. It encouraged foreign producers to sell into the U.S. at competitive prices, and that has caused imports to rise in recent years. Additional capacity to make rubber-processing chemicals in developing countries and Eastern Europe is reducing exports from Western European producers and causing a continued interest in exporting to the U.S., despite continued decline in the value of the dollar.

Higher imports of tires, both those on imported cars and those for replacement sales, have resulted in drastic reductions in U.S. tire production. Consequently, U.S. consumption of rubber by manufacturers has declined. That decline has been exacerbated by the capture of some of the rubber mechanical goods markets by similar products made from plastics. The eventual result, naturally, has been a decline in production and sales of rubber-processing chemicals.

Other significant developments in the industry have been in the chemicals themselves. Producers continue to improve the usefulness of those chemicals by modifying them through changes in structure. They are discovering new compounds that provide desired activities with fewer unwanted side effects and that have reaction rates that reduce the quantities required, saving fabricators money.

Goodyear photo

Truck radiator hoses use variety of rubber-processing chemicals

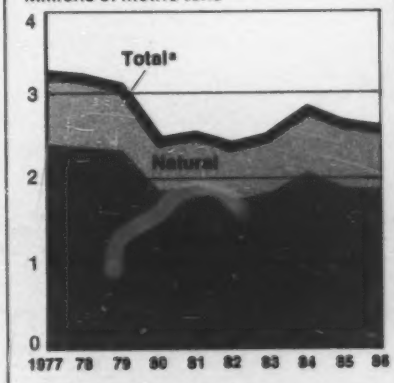
But the decline in U.S. tire production, in terms of units produced, doesn't tell the whole story of the decline in rubber consumption. Last year, tire production was down to 190 million units, or 3.6% less than 1985. More troubling, though, is that 1986 output was down 42 million units, or about 18%, from 1977 production of 232 million.

The fewer tires that were produced by U.S. manufacturers consisted of the much improved radial-ply tires that give much longer life and the smaller tires needed by smaller, lighter cars. Radial tires for cars, trucks, and buses accounted for 79% of the 190 million tires produced in 1986, up from 56% of the 182 million tires produced in 1981. Those two shifts in tire production—in number of tires and type of tires—combine to reduce consumption of rubber and rubber-processing chemicals.

Shipments of tires in the U.S. are up somewhat from a decade ago, which indicates the impact to producers of imported tires. In 1986, shipments increased slightly to a new high of 243 million units, up 7% from 1977 shipments of 227 million units. (The production of 232 million units in 1977 suggests that imports had little effect that year on tire output and rubber and rubber processing chemicals consumption.)

Rubber consumption by manufacturers has declined steadily in the U.S. during the past 10 years, from more than 3.2 million metric tons in 1977 to just over 2.6 million metric tons last year. Consumption of natural rubber, however, has remained nearly constant, at 750,000 metric tons last year, as it did the two preceding years. The decline has occurred in synthetic rubber, with the demand in 1986 at 1.87 million metric tons, down nearly a quarter from the 1977 demand of 2.46 million metric tons. Much of the reduction in consumption has been in styrene-butadiene rubber (SBR), polyisoprene, and nitrile, with new specialty rubbers on the market partially offsetting the decline.

U.S. elastomer demand remains below 1977 level



a Excludes reclaimed. b All types.
Source: Rubber Manufacturers Association

Natural rubbers' share of total rubber use has increased slowly from less than 25% in 1977 to more than 28% last year, owing mainly to the decline in consumption of synthetic rubber. Now that crude oil prices are holding at about two thirds the price prevailing in the first half of the decade, the gain in natural rubber's share of consumption may slow this year. Because negligible amounts of hydrocarbons and energy are used in producing natural rubber, its cost has increased more slowly than that of synthetic rubbers. The shift to radial tires has added to demand for natural rubber because of its lower heat buildup during flexing.

Although declining industrial rubber consumption has had a major impact on demand for rubber-processing chemicals, the shift toward radial tires and an increased use of natural rubber in tires have affected demand, too. For example, radial tires, with their longer life, require more antidegradants—antioxidants and antiozonants—to protect the rubber over longer exposure to weather. Natural rubber requires that more processing chemicals be used to lower its viscosity during fabrication, but much of that requirement for chemicals is offset by a natural antioxidant that is a protective during fabrication, there-

by reducing demand for synthetic antioxidants during fabrication.

In the manufacture and marketing of rubber-processing chemicals, producers have found themselves on a treadmill to provide improved service while at the same time to operate profitably. Not all producers have been able to do that. As a result, a considerable number of producers have left the rubber-processing chemicals business. In little more than a decade, the number of companies reporting production and sales of rubber-processing chemicals to the International Trade Commission has dropped about a third. The number of companies producing those chemicals is expected to decline further in 1987, on the heels of rumors that at least one small producer intends to stop its operations.

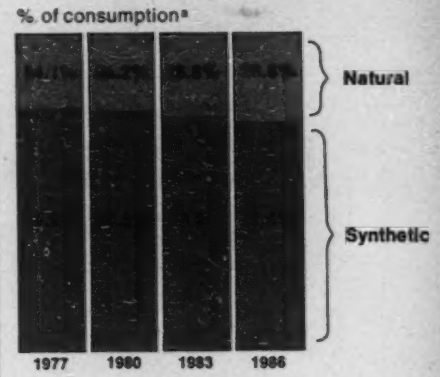
Because of the sharp competition, companies remaining as the suppliers of rubber-processing chemicals have, over the past 10 years, been forced to make many changes in both their production and marketing operations. Companies have undertaken complex arrangements to determine the most profitable ways to run their business. For example, a few producers of rubber-processing chemicals have ended their marketing efforts for some or all of their line. Some continue, however, to manufacture for companies now marketing the chemicals.

Some of the major tire companies have cut back on the number of different rubber-processing chemicals they sell, besides the ones they sell and consume captively. Distributors and importers have added rubber-processing chemicals to their line of marketed products, which adds to the total marketing effort.

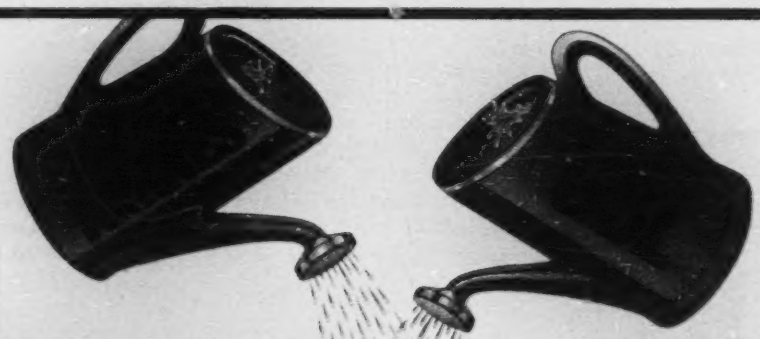
In other cases, a chemical may be made by a single producer and sold to only a handful of specialty fabricators in a volume too small to gain much notice in the total of rubber-processing chemicals. Knowledgeable people in this industry admit they still can't fully grasp all of the myriad marketing arrangements.

Despite changes to product lines and changes in the participants, the rubber-processing chemicals business is falling behind other busi-

Natural rubber slowly gains in share of U.S. elastomer use



a Excludes reclaimed. **Source:** C&EN estimates



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Many compounds used in rubber processing

Of thousands tested, more than 200 organic chemicals and about 20 inorganic chemicals have been found to be useful in fabricating various kinds of elastomers into a host of consumer and industrial products. Before processing, raw rubber has few commercial applications. Compounding rubbers with various chemicals and subjecting the fabricated forms to heat and pressure converts them into useful items such as tires, hoses, and gaskets.

The organic chemicals used in rubber processing and that are included in this report often are complex molecules containing atoms other than carbon, hydrogen, and oxygen. Some of the compounds have been known for more than 100 years to be useful in rubber processing. It is not completely clear how some of the compounds provide the desired properties in the final fabricated rubber product—only that they are essential in providing those properties.

On the average, between 4.5 and 5.0 lb of rubber-processing chemicals are used per 100 lb of rubber during fabrication. Much higher quantities of processing chemicals will go into some rubber products because of the severe conditions to which the product will be subjected. The variety of chemicals used in a formulation, therefore, depends on the product service demands.

Rubber-processing chemicals function in many ways. Antidegradants—antioxidants and antiozonants—are designed to protect rubber polymers both during and after processing. Accelerators speed the crosslinking reaction of polymer with sulfur in the vulcanization process. Activators (sometimes called secondary accelerators) may be used to potentiate accelerators. Other compounds, called retarders, delay vulcanization; certain sulfur donors and peroxides aid vulcanization; and peptizers reduce viscosity.

Some of the organic compounds used by the rubber industry and not covered in this report are peroxides, fatty acids, and sulfur compounds that initiate and regulate polymerization of rubbers. A variety of hydrocarbon oils used to extend and soften polymers also are not covered.

Among other substances not covered in this report are carbon black (used widely as a reinforcement), elemental sulfur (used as a primary vulcanization agent), and various inorganic oxides (used as activators in vulcanization). Numerous carbonates, silica, clays, and pigments used as fillers, reinforcements, and colorants are not covered. Those materials are used in large quantities in rubber fabrication. For example, most tires contain between 1.0 and 1.5 times as much carbon black, oils, and fillers as elastomer.

nesses in profitability, as it continues to be buffeted by overcapacity and rising imports. Prospects for growth in production are very limited. Several of the companies, nevertheless, have maintained large research and development operations that continue to add new products to their line. Many producers are modernizing plants and improving quality control during manufacture and handling of the chemicals, to cut their manufacturing costs.

Monsanto, for example, is completing additions to a rubber-processing chemicals plant located just east of St. Louis. This $18 million unit will not increase capacity but is expected to trim costs of production, says Roger W. Spiller, director, commercial, Monsanto's rubber chemicals division. The company is continuing with its R&D programs in rubber-processing chemicals. One of its latest new products is in the Santoguard line—a scorch (premature curing) delay additive. The company's product line includes antidegradants, accelerators, and vulcanizing agents.

Goodyear continues to put emphasis on rubber-processing chemicals in the antidegradant area. Goodyear, a major captive consumer of these chemicals, also has moved into stabilizers for rubber polymers. A recent development in that line is Wingstay K, a proprietary complex mixture for such rubbers as SBR and nitrile, says Roger O. Gilruth, mar-

ket manager of Goodyear's rubber chemicals division.

Mobay offers a broad line of rubber-processing chemicals, many of which are manufactured by its West German parent, Bayer, and imported into the U.S. The company began producing some antiozonants in the U.S. early in the 1980s with startup of a plant near Charleston, W.Va. A peptizing agent and a bonding system for various substrates are other new products Mobay makes in the U.S.

Producers and marketers of rubber-processing chemicals generally all operate in a similar way. Some, such as Goodrich, sell chemicals through R. T. Vanderbilt, a manufacturer, but best known as a distributor. Pennwalt, a smaller producer of rubber-processing chemicals, is popular for its line of accelerators. Uniroyal Chemical, once a part of Uniroyal, a major tire manufacturer, makes and sells a wide variety of antidegradants and miscellaneous rubber-processing chemicals. Witco's line covers various antidegradants, accelerators, and smaller-volume products such as mold-release agents.

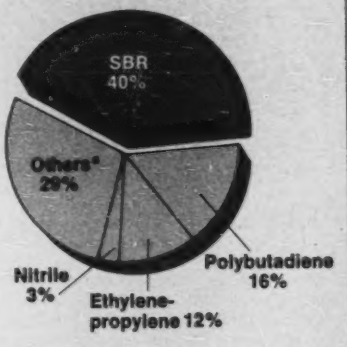
A large number of other companies produce and market rubber-processing chemicals. About half a dozen of them act as distributors, often buying in bulk and repackaging under their own tradenames. Other companies, including some very large ones, such as Du Pont, Ethyl, Eastman Chemical, and W. R. Grace, make antioxidants that have application to a variety of products, including rubber. These companies often do not consider themselves part of the rubber-processing chemicals industry but, rather, a part of the larger specialty organic chemicals industry.

The major U.S. producers of rubber-processing chemicals also have plants in other parts of the world, notably in Western Europe. Those plants are used in a variety of ways to meet market demands throughout the world, while keeping as their objective the best combination of service and profitability. Some producers, for example, use their foreign plants to supplement capacity in the U.S., if their domestic capacity is insufficient to meet sales requirements. The foreign plants also are used to make chemicals that are in demand in the U.S. but for which there are no units in the U.S. to make them. Conversely, U.S. capacity is used to supply markets in other parts of the world that cannot be met by production in foreign plants.

Many rubber-processing chemicals are reported to the International Trade Commission as having a single producer or vendor. In 1985, only one chemical was reported as having five sources. Two others had only four sources. Nine chemicals had three sources. Nearly 100 were reported by a single company.

Analysis of the actual consump-

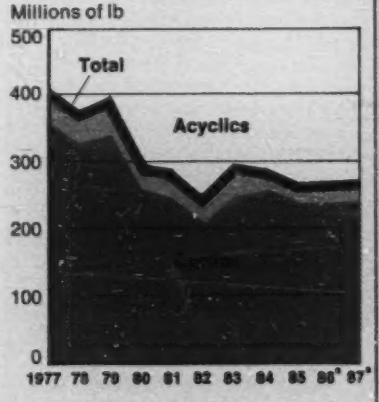
SBR still largest-volume U.S.-made synthetic rubber



Total 1986 production = 1.99 million metric tons

a Butyl, polyisoprene, polychloroprene (neoprene), silicone, and miscellaneous synthetic elastomers.
Source: Rubber Manufacturers Association

Rubber chemical output below earlier levels



a C&EN estimates.
Source: U.S. International Trade Commission

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Although output is down, tires still consume large quantities of chemicals

tion of the wide variety of these chemicals is difficult. There is considerable overlapping in their uses in rubber fabrication, as well as in other industries such as plastics, in which the same properties are desired as in rubber.

The wide variety of rubber-processing chemicals, however, can be classified, either by their functional activity or by their structural type. Two functional classes—antidegradants and accelerators—account for more than 90% of estimated U.S. consumption of those chemicals, which in 1987 will total about 225 million lb. Antidegradants will account for about 120 million lb of that total and accelerators about 80 million lb. The remaining functional classes are vulcanizing agents, peptizers, retarders, blowing agents, and some miscellaneous chemicals. None of those functional classes of chemicals will grow very fast between now and 1990; some will have little or no growth and others may have 1 to 2% growth.

Of the 120 million lb of antidegradants that will be consumed in fabricating rubber products in the U.S. this year, about 60 million lb will consist of a variety of phenylenediamines. Another 16 million to 18 million lb will be phosphites. Various phenolic compounds will account for a slightly smaller amount. Quinolines use will amount to more than 12 million lb. Diphenylamines and others will total 15 million to 18 million lb.

Of the 80 million lb or so of accelerators (catalysts that aid the vulcanization process) used this year, nearly half will be sulfenamides. Other important accelerator compounds include benzothiazoles (16 million to 18 million lb), dithiocarbamates (less than 4 million lb), and thiurams (about 3 million lb). A large number of other compounds, many containing nitrogen, and blends of accelerator chemicals will total about 15 million lb.

Antioxidants, a major type of antidegradant, have a long history. They were first sought more than

Sales value, average prices of rubber-processing chemicals changed little during 1980s

	Cyclics		Acyclics	
	Value of sales ($ millions)	Average selling price ($ per lb)	Value of sales ($ millions)	Average selling price ($ per lb)
1977	$248.7	$1.23	$29.0	$0.81
1978	258.3	1.29	26.8	1.03
1979	316.2	1.35	28.9	0.83
1980	269.9	1.61	26.1	1.00
1981	270.9	1.72	27.4	1.14
1982	240.7	1.78	22.9	1.21
1983	279.2	1.72	33.1	0.82
1984	259.6	1.69	25.6	1.18
1985	280.7	1.81	22.2	1.14
1986*	275	1.56	21	1.10

Note: Merchant sales quantities are well below reported production because of large captive demand. *C&EN estimate. Source: U.S. International Trade Commission

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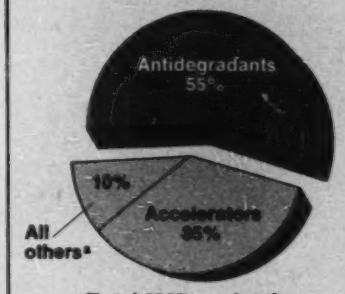
100 years ago, when fabricated rubber products were short-lived. Loss of flexibility (and subsequent cracking) and increased stickiness that caused undesirable adherence to surfaces (such as skin) were serious problems. Prior to 1910, pitch, creosote, and naphthalene from coking coal were among the more sophisticated materials used to protect rubber against deterioration.

In subsequent years, these problems were partially alleviated by the use of organic chemicals purified from coal tar or derivatives synthesized from those organic chemicals. Useful compounds included aniline, various cresols, hydroquinone, phenol, and various simple amine and hydroxy derivatives of these compounds.

That range of derivatives laid groundwork for the development and testing of other more sophisticated derivatives, especially secondary aromatic amines. After World War II, when the use of synthetic rubber in many new ways increased rapidly, a need was created for nondiscoloring antioxidants. The oxygenated compounds had held promise, but they also presented difficulties. To meet the need for such antioxidants, chemists made more complex phenol derivatives that were much more effective.

Antioxidants and antiozonants are used to resist the formation of peroxides at points along a rubber polymer chain. The formation results from a hydrogen atom being knocked off by energy (such as heat or light), according to Goodyear. The loss of hydrogen creates a radical that reacts with oxygen to form the peroxide. Subsequently, the newly formed peroxide can remove another hydrogen atom from the same or another polymer chain, which then produces another radical and a hydroperoxide. If two hydroperoxides react, a rubber alkoxy radical and another rubber peroxide form. Both of the radicals then remove hydrogen from polymer chains and the polymer destruction accelerates.

Antidegradants dominate rubber-processing chemicals



Total 1987 production = 265 million lb

[a] Vulcanizing agents, peptizers, retarders, and blowing agents.

The net effect obtained from the process varies, depending on the kind of rubber polymer involved. Natural or polyisoprene rubbers soften as the result of chain-breaking and depolymerization. SBR and specialized rubbers (such as the urethanes, fluorinated elastomers, acrylics, and some silicone elastomers) harden because of cross polymerization of chains.

Chemical methods to minimize degradation involve a reaction of the chemicals with the peroxides that form when a hydrogen atom is removed from the rubber polymer chain. In one method, a hydrogen from the antioxidant, reacting with the peroxide, leaves a radical from the antioxidant. The radical then reacts with another peroxide, prevents the peroxide from removing a hydrogen from the polymer chain and from continuing the degradation process. Another method involves using antioxidants that react with the hydroperoxides.

The most common antioxidants that react with the peroxides formed by removal of hydrogen atoms are phenols, phosphites, and certain alkyl and aromatic amines, according to Goodyear. Numerous other compounds have some value as antioxidants, but they also have drawbacks that limit usefulness in conventional vulcanization systems.

The phenols (including bisphenols) have relatively large substituent groups on them and are generally known as hindered phenols.

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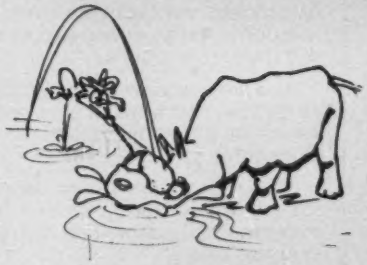

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The substituent groups may include styrene, alkyls of varying complexity, and combinations of these. The most widely used antioxidant of this group probably is the very active 2,6-di-*tert*-butyl-*p*-cresol.

The bisphenol antioxidants are similar in substituent structure to the phenols. They can be joined together at varying points on the ring as is desired. A sulfur atom sometimes is contained in the bridge structure and forms a compound that is quite active but causes some staining of the final product. The increased size of the molecule reduces its volatility, a property important to retention of the antioxidant for giving longer protection.

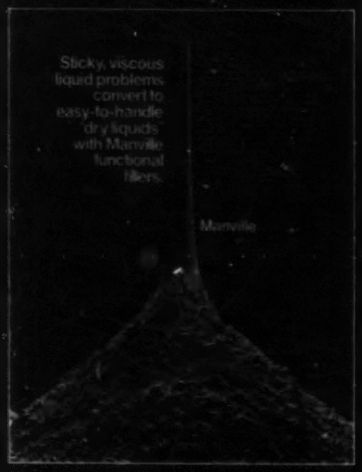
Other phenolic antioxidants are polyphenols and hydroquinone derivatives. The polyphenols have properties generally similar to bisphenols. The hydroquinones, with two hydroxyl groups on the ring, have properties that make them useful as stabilizers. They are often used in compounds containing polymers that otherwise would continue to polymerize during processing and storage. Many mixtures and blends of the phenolic antioxidants are commercially available for use in special circumstances.

A large number of alkyl and aromatic amines are used as antioxidants because of development of what has been called the first effective long-term antioxidant, phenyl-β-naphthylamine. As a class, the alkyl/aryl amines show wide variations in their resistance to direct oxidation. That factor is important to long-lasting protection for the rubber. This class of compounds is important among antidegradants for rubber and other materials such as plastics, because of their susceptibility to oxidation, which allows them to be oxygen scavengers.

Over the years, the types of amines used as antidegradants have shifted, as one or another compound has tested more favorably for a given fabricated rubber product. An example: Very few naphthylamines are used now.

The largest-volume amine antidegradants now sold are the *p*-phenylenediamine derivatives. This year about 60 million lb likely will be sold. The volatility, resistance to direct oxidation, and other properties of these compounds vary widely, making their selection difficult for rubber fabricators. At the same time, the various kinds and sizes of substituent groups allow broad adjustments to properties of a finished product. The *p*-phenylenediamines have either high or low reactivity as antiozonants in addition to being powerful antioxidants. They can stain modestly or heavily, and they can resist side-reactions with oxygen quite well or are rapidly deactivated. The *p*-phenylenediamines with both alkyl and aryl substituent groups frequently are blended with other types to modify either the physical form or the performance characteristics.

Technician at Monsanto's expanded rubber chemicals research center in Akron



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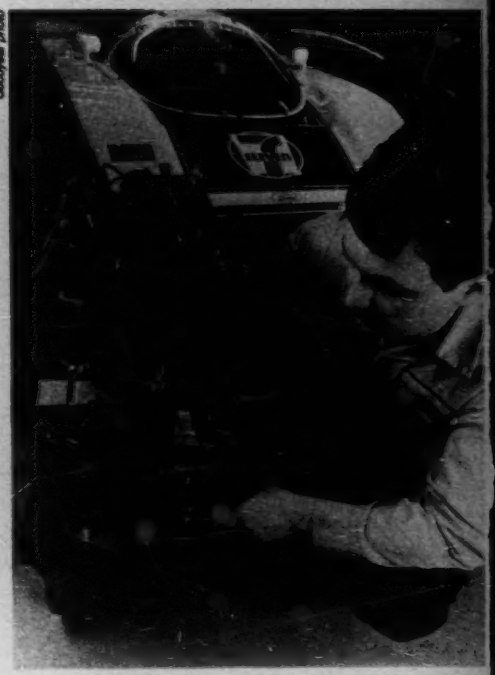
The quinolines constitute the second largest group of antidegradants. Relatively few derivatives of quinoline are of commercial importance, but some are sold in significant quantities. Polymerized 2,2,4-trimethyl-1,2-dihydroquinoline probably has the largest use where good aging and heat resistance are desired, even if some discoloration occurs.

Other commercially important amine antidegradants are the diphenylamines and various aldehyde-amine products. Diphenylamine can be combined with various alkyl and aromatic groups to make useful antioxidants. Both of those groups of derivatives have commercial significance. The alkylated derivatives are more volatile than are the aromatic ones. A styrenic derivative supplied by Goodyear may be substituted for phenolic antioxidants in compounds containing carbon black, which partially absorbs phenolic antioxidants.

The volume of various phosphites used as antioxidants will about equal or possibly surpass the volume of phenolics consumed this year. Both alkyl and aryl derivatives can be made. However, the majority of commercially important phosphite antioxidants are aryl-substituted. Some forms of phosphites having a small polymer (such as polypropylene glycol) between phosphorus atoms have been found to partially overcome a shortcoming, hydrolysis, of the most widely used form, tris-nonylphenol phosphite. All common phosphites are destroyed during vulcanization. Blends of phosphites and phenolic antioxidants frequently are used in rubber compounds.

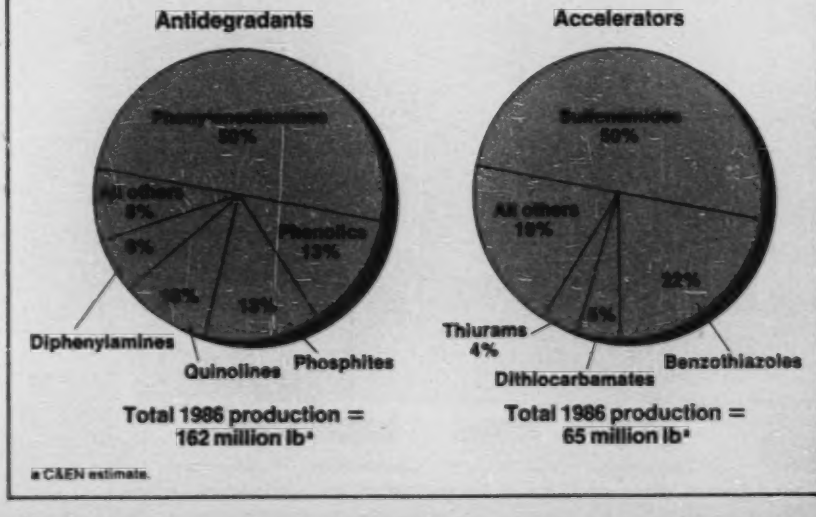


Goodyear photo

Engine builder adjusts tension on premium drive belt for race car engine

Many of the antioxidants also are effective antiozonants, but the most important antiozonants are the various *p*-phenylenediamines. Dialkyl-, diaryl-, and alkylaryl-*p*-phenylenediamines are produced with each group having somewhat different

Antidegradants, accelerators comprise several chemicals



*C&EN estimate.

properties. Other antiozonants used in rubber processing include derivatives of urea, thiourea, and certain metal dithiocarbamates, although the volumes consumed of any of those are small compared with the *p*-phenylenediamines.

Using organic chemicals as antiozonants isn't the only way to protect rubber from ozone. If conditions do not involve flexing of the rubber, wax can be added to the compound. The wax moves to the surface and forms a film that is a barrier to ozone. When the film is broken by flexing, however, ozone will attack at the break with stress concentrated at the break, harming the rubber more than it possibly would otherwise.

Highly unsaturated rubbers, such as SBR, polybutadiene, and polyisoprene, are attacked more heavily by ozone than are highly saturated rubbers such as terpolymers of ethylene, propylene, and diene monomers (EPDM). In some rubber compounds, addition of EPDM to natural rubber or SBR will increase resistance to ozone with minimal loss of desired properties.

Before most antidegradants begin their work of protecting fabricated rubber products, the second largest group of rubber-processing chemicals comes into play. That group, the accelerators, catalyzes the vulcanization (or curing) process by aiding the crosslinking of rubber polymer chains with sulfur. After the crosslinking process, the product is elastic. The most important result from the development and use of accelerators is the vastly increased efficiency in rubber processing and fabrication. Use of sulfur alone to vulcanize rubber requires long reaction times. By vulcanizing in relatively short times, processors can add to the rubber compounds materials that provide desired properties but that would be completely destroyed during long curing times.

The first accelerators (although not recognized as catalysts) were metal oxides. The first organic accelerator was aniline, which was first used for that purpose early in the 20th century. Aniline is no longer used because of its toxicity and technical difficulties, but some of its derivatives are still used. During the past 75 years, several thousand organic chemicals have been tested as rubber vulcanization accelerators, but less than 100 have found commercial use. Two classes of compounds—sulfenamides and benzothiazoles—account for more than two thirds of consumption.

Despite intensive research on the vulcanization process, the exact mechanism by which accelerators work remains uncertain. Most chemists agree that the accelerator, which contains sulfur atoms, attacks the elemental sulfur to form a polysulfide adduct. The adduct then becomes attached to the polymer chain with the accelerator opposite the chain, and a crosslink results through the polysulfide groups. Up to a point, a low level of sulfur in the crosslinkage improves stability of the rubber and its elasticity.

The discovery of 2-mercaptobenzothiozole more than 60 years ago as an efficient vulcanization accelerator brought about the various de-

Goodyear photo

Ford worker installs rubber air spring in wheel well of Lincoln Continental

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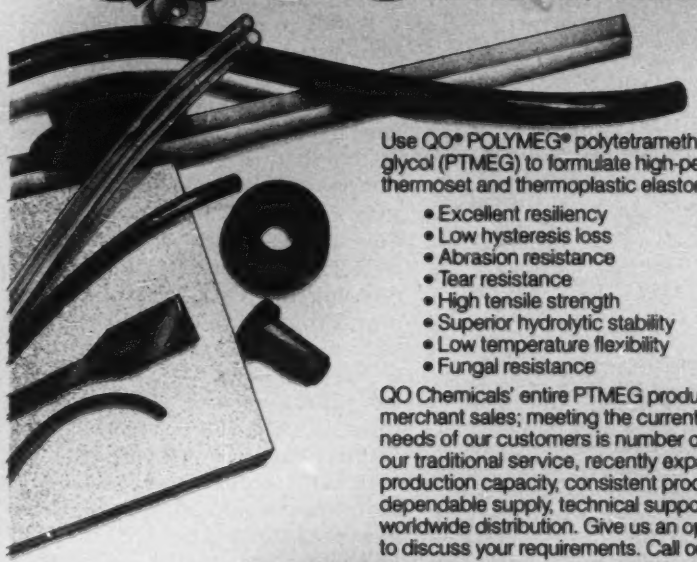

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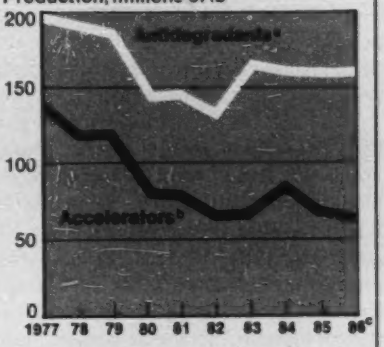
layed-action accelerators used today for high output rates of rubber products. Derivatives of the compound remain the widely used sulfenamides. Three sulfenamide derivatives are estimated to account for about 90% of the total accelerators used in the U.S. annually. They go largely into tires. Tire makers like the products because they have long scorch delays and provide good cure rates. The properties can be widely varied, however, according to selection of the amine used, so that the scorch delay is increased by more hindrance in the molecular structure, or less basic amines such as morpholine are used.

Other accelerators with significant demand include various dithiocarbamates and their derivatives. These reactive compounds are used as intermediates in making other chemicals, such as pesticides, and also are used in other processing, which makes accurate estimates of consumption in rubber fabrication difficult. The derivative list is large because of simplicity of formation. Very specialized uses take tiny quantities of some of these derivatives in a host of nontire rubber products.

From the dithiocarbamates, or sodium salts, comes another group of compounds—the thiurams. Many of those compounds provide the high cure rates of the dithiocarbamates. They sometimes are used as activators to increase cure rates with other, less reactive accelerators.

Cyclic antidegradants and accelerators still down



a Antioxidants, antiozonants, and stabilizers.
b Accelerators, activators, and vulcanizing agents.
c C&EN estimate.
Source: U.S. International Trade Commission

Other classes of compounds have some use as accelerators, but more often they are activators for other accelerators. Guanidines and products from reactions of certain aldehydes and amines to give undefined structures are examples. Those products go mostly into specialty cures, and the amount consumed this year could total about 5 million lb.

To obtain the efficient vulcanization systems that fabricators desire, a poorly defined group of chemicals, known as vulcanizing agents, have developed over the years. Generally, they are considered to be compounds that can donate a sulfur atom during vulcanization. Some of the compounds are accelerators as well. In a stricter definition, a vulcanizing agent must be a sulfur donor. A compound that is an organic sulfur donor might be used and, frequently, will produce an accelerator group as well. Thiuram sulfides are examples of active agents. Because the thiuram sulfides provide little scorch delay, some thiomorpholines and morpholinothiobenzolthiazoles are used. If a delayed-action accelerator is combined with a thiomorpholine, more scorch delay will be obtained.

About 75 years after sulfur was found to be the key to rubber vulcanization, a different but similar technology was discovered—peroxide cures. It wasn't until sometime after World War II that peroxide cures with rates useful in volume production of rubber products came into wide use. The process by which classes of compounds, such as dialkyl peroxides, cure rubber begins when free radicals that result from homolytic decomposition of the peroxide produce alkoxy radicals. These radicals remove a hydrogen atom from a polymer chain, to give an alkyl radical on the polymer chain. The radicals on polymer chains join to form crosslinkages.

The carbon-to-carbon bonds in these kinds of crosslinks have higher bond energies than do the sulfur-sulfur and sulfur-carbon bonds of vulcanizations that involve sulfur. Consequently, the products are more thermally stable than sulfur-cured vulcanizates. Peroxide cures generally are more uniform than sulfur cures and result in fabricated products with properties associated with stable crosslinks; for example, heat resistance and low compression set.

Peroxide cures have the disadvantage of causing different effects on different rubber polymers. There is also the need for the peroxide to decompose as completely as possible before the polymer mixture is exposed to oxygen. A third disadvantage is that peroxides are liable to react with other chemicals, such as antidegradants, added to the compound. Rubber polymers with high amounts of hydrogen on tertiary carbon atoms, such as butyl rubber, are less suitable for peroxide cures because radicals on chains are liable to cause the chains to break when crosslinking occurs. The antiozonants of the *p*-phenylenediamine group especially limit peroxide cures, because they are good traps for radicals.

The volume of alkyl peroxides used in rubber compounding is small at about 1.5 million lb. A big share of that volume is dicumyl peroxide. A variety of additives are used in small volume to improve peroxide cures, many of which have combination structures of olefins and functional groups.

Vulcanization retarders are another group of rubber-processing chemicals sold in relatively small vol-

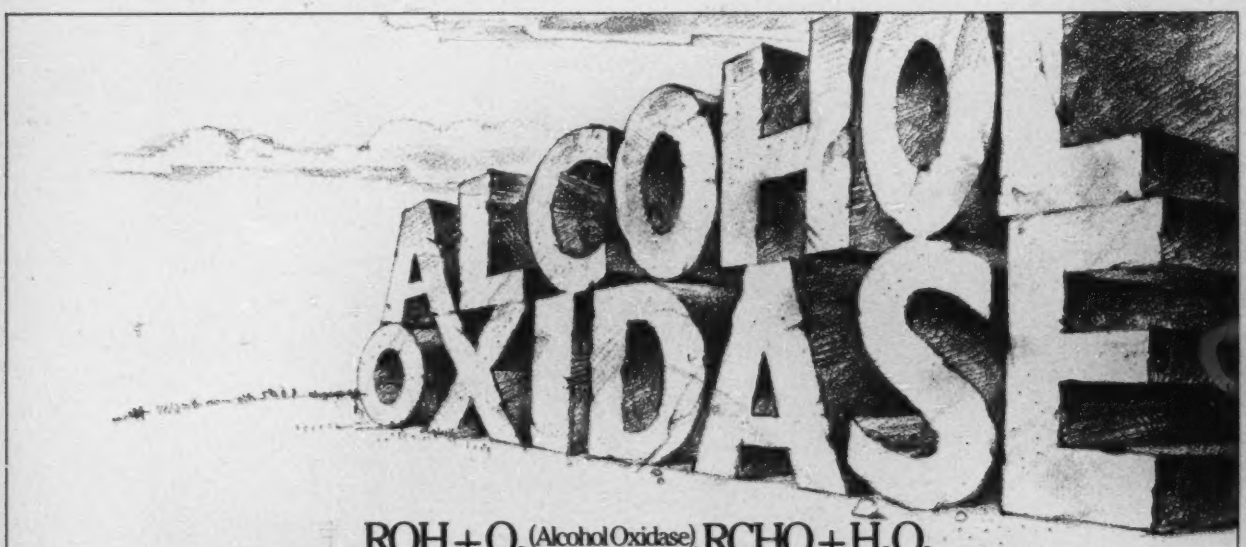
Goodyear photo

Conveyor belts comprise large part of nontire rubber market

Specially designed hose is used to fill oak tanks at California winery

ume, about 3 million lb this year. These chemicals have various other names indicative of their action: antiscorching agents, cure retarders, and prevulcanization inhibitors. Over time, the specific retarder used in the largest volume changes, as has been the case with many rubber-processing chemicals. At one time, benzoic acid and a phenylamine derivative dominated the market. Now, *N*-(cyclohexylthio)phthalimide is predominant because it doesn't stain, it works well with many antidegradants and accelerators, and it is relatively nontoxic. This and other compounds now used in smaller quantities have minor effects on the cure rate, on physical properties, and on degradation of the fabricated product. By far the largest use of retarders is in tire manufacturing, because they allow delays after assembly to give flexibility in the overall tire-production process.

A large number of other rubber-processing chemicals are used by fabricators, depending on the product they are making. To overcome the difficulties in mastication and dispersion of additives, many different plasticizers and softeners are used. Some are mixtures of natural products and act as lubricants. Others are plasticizers or peptizers and act chemically to retard repolymerization of chains broken during mastication. The peptizers are often thiophenols and are used in relatively



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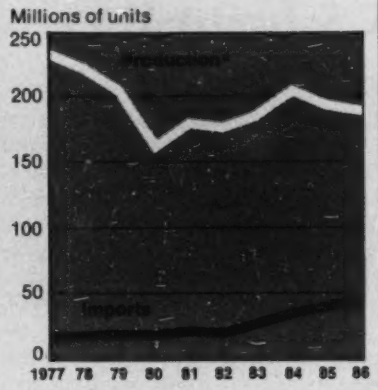
U.S. tire production fell as imports rose



a Passenger car plus truck and bus.
Sources: Rubber Manufacturers Association, Department of Commerce

low concentrations. Sales volume this year probably will total about 3 million lb.

Other materials added to rubber compounds as processing aids are diverse in composition. Some have little effect on properties of the finished rubber product; others may have major effects that are offset by use of still other additives. These materials range from common fatty acids to various esters, and the results of using them vary widely, depending on the rubber polymer. A variety of resins are used as aids in dispersion of fillers, reinforcing agents, and sulfur, and they may provide tack as an aid in assembly of the rubber product.

The diversity and complexity of rubber-processing chemicals have developed because of the importance of aids to making rubber products useful in almost all areas of consumer products. As consumer demands change, the processing chemicals to meet rubber fabricators' demands also will change. However, these changes will keep the rubber-processing chemicals industry viable and give producers options in their programs to improve profitability. The changes also are expected to provide returns on current R&D programs, through rapid increases in sales of new products. Fewer producers of rubber-processing chemicals may survive during the next decade, but those that remain could have a better business. □

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ACS Committee on Professional Training 1986 Annual Report

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society decreased 4.1% in the 1985–86 academic year from the previous year. The number of master's degrees from these departments stayed the same and the number of Ph.D. degrees continued to rise for the seventh year in a row, this year 4.2%. These departments project that in 1987 the number of bachelor's degrees will decrease 1.8%, master's will increase 9.6%, and Ph.D. degrees will increase 14.2%. (It should be noted, however, that these projections are usually higher than actual counts a year later.)

The percentage of baccalaureate graduates certified to ACS was 42%, the same as last year. (Certified graduates are those who have completed the curriculum specified by the Committee on Professional Training and are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

A total of 2269 of the bachelor's degree graduates from the approved schools were reported as planning to go to graduate school, and 1926 reported plans to go to professional schools.

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1985–86 by departments whose chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering & Technology. (These departments are not required to report their data to CPT, so the number of departments included varies each year.) Included for the fourth year is a table with information on graduate student enrollments in chemistry departments whose undergraduate programs are ACS approved.

Summary of totals from 1986 reports from approved schools

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, total	580	5948	3347	9295
Certified		2512	1380	3892
Noncertified		3436	1967	5403
Masters	315	1056	564	1620
Doctorates	187	1496	389	1885
CHEMICAL ENGINEERING				
Bachelors, certified	118	3900	1329	5229
Masters	116	1023	221	1244
Doctorates	103	408	52	460

Summary of data from approved schools, 1982–86

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1982	561	9,866	4179	5687	322	1646	187	1683
1983	570	10,043	4233	5810	320	1569	189	1759
1984	577	9,819	4201	5618	321	1637	189	1777
1985	579	9,679	4021	5658	316	1621	186	1806
1986	580	9,295	3892	5403	315	1620	187	1885
CHEMICAL ENGINEERING[a]								
1982	113	5,963	5963	—	109	1171	92	293
1983	122	7,021	7021	—	116	1317	101	333
1984	120	6,866	6866	—	114	1436	101	367
1985	123	6,442	6442	—	118	1489	104	418
1986	118	5,229	5229	—	116	1244	103	460

[a] Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

The number of bachelor's degrees in chemical engineering from the 118 AIChE-ABET-accredited departments that reported in 1986 decreased 23% from the total reported by 123 departments in 1985, the third decrease in a row. These 118 departments reported an expected further decrease in bachelor's degrees of 10.5% in 1987. At the graduate level, the number of chemical engineering master's degrees decreased for the first time and Ph.D. degrees increased for the seventh year in a row. The number of master's degrees was down 19% from 1985, and the number of Ph.D.s was up 9.1%. Projected 1987 numbers of master's and Ph.D. degrees in chemical engineering from these schools are up less than 1% for master's degrees and 32% for Ph.D.s.

The chemistry programs at ACS-approved schools normally are reevaluated at five-year intervals. There were 580 colleges and univer-

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full time	Part time	Full time	Part time
M.S. departments[a]					
Fall 1982	131	494	310	1075	1048
Fall 1983	132	452	293	1098	981
Fall 1984	131	468	270	1099	990
Fall 1985	129	364	229	930	772
Ph.D. departments					
Fall 1982	189	3412	306	13,488	1483
Fall 1983	189	3554	275	14,037	1380
Fall 1984	186	3404	227	14,194	1314
Fall 1985	187	3947	501	15,576	2334

a Departments whose highest offering is the master's degree in chemistry.

Committee members, 1986

Alice J. Cunningham, *chairwoman*
Agnes Scott College
Henry A. Bent
North Carolina State University
Robert C. Brasted (deceased)
University of Minnesota, Minneapolis
Marjorie C. Caserio
University of California, Irvine
Michael P. Doyle
Trinity University
C. David Gutsche
Washington University
Gordon G. Hammes
Cornell University
Herbert D. Kaesz
University of California, Los Angeles
Karen W. Morse
Utah State University
Jere P. Segrest
University of Alabama, Birmingham
Shelby W. Shelby
Ethicon Inc.
Richard P. Van Duyne
Northwestern University
Ernest L. Eliel, *consultant*
University of North Carolina, Chapel Hill
Harry B. Gray, *consultant*
California Institute of Technology
Peter Lykos, *consultant*
Illinois Institute of Technology
Melvin B. Robin, *consultant*
AT&T Bell Laboratories
Barbara A. Gallagher, *committee secretary*
Cathy A. Nelson, *staff associate*
Dolphine S. Hite, *program assistant*
American Chemical Society

sities on the approved list at the end of 1986. During the year the committee studied the chemistry programs of 170 of the approved schools and of 19 schools applying for ACS approval. Each evaluation involved a review of extensive documentary materials submitted by the department chair describing the current status of the program.

Four schools were added to the ACS-approved list by CPT in 1986; two were put on probation; one was removed from probation; five continued on probation; and three were removed from the list. At year's end, 580 colleges and universities had ACS-approved undergraduate chemistry programs.

At its meeting in April 1986, the ACS Board of Directors unanimously endorsed the CPT proposal for development of a program for approval of alternate degrees. Subsequently, the committee has devoted considerable time and effort toward establishing guidelines for alternate degrees. In addition to the traditional bachelor's degrees in chemistry, guidelines for approved degrees with emphasis in biochemistry or polymer chemistry have been developed initially. Guidelines for chemistry degrees with other emphases are currently under consideration. The basic design is that of a required three years of studies for any chemistry and advanced or correlative study essential for the emphasis area.

In 1986 CPT marked its 50th anniversary with a symposium and reception during the ACS national meeting in New York City. The symposium dealt with changes in higher education programs that accompany and must accommodate rapid changes in chemistry.

As part of the process of evaluating approved chemistry programs, the committee considers library journal holdings. To guide departments in developing chemistry libraries and to aid the committee's work, CPT has developed a list of recommended journals and related materials. This list will be made available in a 1987 edition of the *CPT Newsletter*.

Departments of forensic science and toxicology have requested that the ACS Directory of Graduate Research (DGR) be expanded to cover these disciplines. The committee has been reviewing programs in these areas in an effort to determine if the chemistry content of forensic science and toxicology programs warrants inclusion in the DGR.

Other CPT activities in 1986 included continued interaction with the ACS Society Committee on Education Task Force on ACS Involvement in the Two-Year Colleges; development of a program for a conference to address the concerns of small colleges on the ACS-approved list; review of the Target 2000 report; review of the Pimentel report, "Opportunities in Chemistry"; discussion of content of freshman general chemistry courses with the Division of Chemical Education; compilation of the responses to the science/chemistry building construction survey; participation in an electronic mail experiment; and continuation of a project to computerize all data received from ACS-approved schools.

The committee would like to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or applying for ACS approval during 1986: Glenn A. Crosby, Washington State University; Roger L. DeKock, Calvin College; Arthur Fry, University of Arkansas; Heinz F. Koch, Ithaca College; William R. Moomaw, Williams College; Ronald M. Pike, Merrimack College; Jean'ne M. Shreeve, University of Idaho; Gene G. Wubbels, Grinnell College. □

Chemistry and chemical engineering degrees awarded by approved schools, 1985–86

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	2	3	3	—	—	—	—
Adelphi U	2	1	2	—	—	—	—
Agnes Scott C	2	1	—	—	—	—	—
Akron, U of	23	4	6	1	a	—	—
Alabama, U of							
University	2	11	1	5	32	4	0
Birmingham	1	2	5	1	—	—	—
Huntsville	0	5	1	—	a	—	—
Alaska, U of	6	0	3	—	—	—	—
Albion C	2	23	—	—	—	—	—
Albright C	1	15	—	—	—	—	—
Alfred U	1	0	—	—	—	—	—
Allegheny C	0	24	—	—	—	—	—
Alma C	2	7	—	—	—	—	—
American U	4	5	6	7	—	—	—
Amherst C	0	10	—	—	—	—	—
Andrews U	3	9	—	—	—	—	—
Appalachian State U	7	4	1	—	—	—	—
Arizona State U	18	8	4	17	40	7	3
Arizona, U of	25	30	12	15	33	10	3
Arkansas, U of							
Fayetteville	2	14	0	11	51	16	5
Little Rock	3	1	2	—	—	—	—
Ashland C	1	7	—	—	—	—	—
Auburn U	9	26	3	6	47	9	4
Augsburg C	4	8	—	—	—	—	—
Augustana C							
Illinois	1	14	—	—	—	—	—
South Dakota	2	9	—	—	—	—	—
Austin C	1	8	—	—	—	—	—
Baldwin-Wallace C	1	8	—	—	—	—	—
Ball State U	9	5	4	—	—	—	—
Barnard C	0	19	—	—	—	—	—
Bates C	3	10	—	—	—	—	—
Baylor U	13	9	2	3	—	—	—
Beloit C	2	9	—	—	—	—	—
Bemidji State U	4	4	—	—	—	—	—
Birmingham-Southern C	5	15	—	—	—	—	—
Bloomsburg U	7	1	—	—	—	—	—
Boston C	19	0	7	3	—	—	—
Boston U	4	19	7	8	—	—	—
Bowdoin C	4	36	—	—	—	—	—
Bowling Green State U	5	9	4	—	—	—	—
Bradley U	3	7	0	—	—	—	—
Brandeis U	0	9	1	12	—	—	—
Bridgeport, U of	1	0	5	—	—	—	—
Bridgewater State C	1	3	2	—	—	—	—
Brigham Young U	9	33	1	8	53	6	2
Brown U	0	14	3	10	4	2	1
Bryn Mawr C	19	0	0	1	—	—	—
Bucknell U	6	12	6	—	29	2	—
Butler U	2	13	5	—	—	—	—
California Institute of Tech	9	0	5	29	11	13	13
California Polytechnic State U	5	24	5	—	—	—	—
California State C							
Bakersfield	6	2	—	—	—	—	—
Stanislaus	3	5	—	—	—	—	—
California State Polytechnic U	4	11	3	—	a	—	—
California State U							
Chico	2	12	—	—	—	—	—
Dominguez Hills	0	3	—	—	—	—	—
Fresno	11	4	3	—	—	—	—
Fullerton	5	16	8	—	—	—	—
Hayward	13	4	2	—	—	—	—
Long Beach	17	18	5	—	a	—	—
Los Angeles	12	0	5	—	—	—	—
Northridge	10	13	2	—	—	—	—
Sacramento	11	6	7	—	—	—	—
San Bernardino	0	5	—	—	—	—	—
California, U of							
Berkeley	70	1	11	69	89	18	13
Davis	30	7	2	15	34	3	3
Irvine	18	48	7	17	—	—	—
Los Angeles	27	73	12	29	11	8	5
Riverside	7	3	7	8	—	—	—
San Diego	46	0	12	25	28	3	1
Santa Barbara	24	9	9	22	a	—	—
Santa Cruz	0	22	6	9	—	—	—
Calvin C	6	6	—	—	—	—	—
Canisius C	10	3	—	—	—	—	—
Capital U	2	5	—	—	—	—	—
Carleton C	3	27	—	—	—	—	—
Carnegie-Mellon U	20	2	10	4	52	12	11
Carroll C	4	10	—	—	—	—	—
Carthage C	2	3	—	—	—	—	—
Case Western Reserve U	4	35	12	22	35	17	4
Catholic U of America	0	0	0	4	a	—	—
Centenary C of Louisiana	1	2	—	—	—	—	—
Central C	1	4	—	—	—	—	—
Central Connecticut State U	5	0	0	—	—	—	—
Central Florida, U of	14	0	6	—	—	—	—
Central Michigan U	5	18	5	—	—	—	—
Central State U							
Ohio	2	3	—	—	—	—	—
Oklahoma	4	7	—	—	—	—	—
Centre C	3	2	—	—	—	—	—
Charleston, C of	7	4	—	—	—	—	—
Chatham C	2	1	—	—	—	—	—
Chestnut Hill C	5	4	—	—	—	—	—
Chicago, U of	11	23	8	18	—	—	—
Christian Brothers C[b]	—	—	—	—	a	—	—
Cincinnati, U of	22	0	20	13	53	11	1
Citadel, The	5	5	—	—	—	—	—
City U of New York							
Graduate Center	—	—	—	18	—	—	—
Brooklyn C	0	31	2	—	—	—	—
City C	6	15	5	—	a	—	—
Herbert H. Lehman C	2	10	—	—	—	—	—
Hunter C	1	8	—	—	—	—	—
Queens C	3	21	1	—	—	—	—
Clarion U of Pennsylvania	8	0	—	—	—	—	—
Clark U	3	3	7	1	—	—	—
Clarkson U	7	10	3	3	87	11	9
Clemson U	7	3	2	1	57	7	1
Cleveland State U	17	0	9	6	33	11	1
Coe C	0	6	—	—	—	—	—
Colby C	3	9	—	—	—	—	—
Colgate U	4	5	—	—	—	—	—
Colorado C	4	5	—	—	—	—	—
Colorado School of Mines	14	0	4	1	84	18	2
Colorado State U	19	13	3	17	24	11	0
Colorado, U of							
Boulder	6	46	7	14	52	13	4
Colorado Springs	9	2	—	—	—	—	—
Denver	2	8	1	—	—	—	—
Columbia U	8	10	21	15	29	21	5
Concordia C	3	7	—	—	—	—	—
Connecticut, U of	26	13	3	11	59	14	1
Cooper Union[b]	—	—	—	—	a	—	—
Cornell C	0	5	—	—	—	—	—
Cornell U	24	35	36	30	33	6	6
Creighton U	0	18	3	—	—	—	—
Dartmouth C	0	17	0	2	—	—	—
David Lipscomb C	0	13	—	—	—	—	—
Davidson C	4	5	—	—	—	—	—
Dayton, U of	7	9	1	—	33	4	—
Delaware State C	1	2	—	—	—	—	—
Delaware, U of	41	14	8	11	49	10	11
Delaware Valley C of Science & Agriculture	13	0	—	—	—	—	—
Delta State U	0	20	—	—	—	—	—
Denison U	4	12	—	—	—	—	—
Denver, U of	7	10	4	5	—	—	—
De Paul U	1	5	2	—	—	—	—
DePauw U	7	11	—	—	—	—	—
Detroit, U of	4	0	10	2	a	—	—
Dickinson C	1	16	—	—	—	—	—
Drake U	1	2	—	—	—	—	—
Drew U	1	10	—	—	—	—	—
Drexel U	14	0	11	3	67	7	4
Duke U	15	44	0	13	—	—	—
Duquesne U	3	5	5	1	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Earlham C	0	8	—	—	—	—	—
East Carolina U	7	1	0	—	—	—	—
East Stroudsburg U	7	4	—	—	—	—	—
East Tennessee State U	6	4	3	—	—	—	—
East Texas State U	4	3	3	—	—	—	—
Eastern Illinois U	5	3	4	—	—	—	—
Eastern Kentucky U	2	14	2	—	—	—	—
Eastern Michigan U	1	30	9	—	—	—	—
Eastern New Mexico U	1	8	0	—	—	—	—
Eckerd C	2	4	—	—	—	—	—
Elizabethtown C	2	6	—	—	—	—	—
Elmhurst C	1	15	—	—	—	—	—
Emory U	2	43	4	8	—	—	—
Emporia State U	0	4	0	—	—	—	—
Evansville, U of	2	8	—	—	—	—	—
Fairfield U	11	1	—	—	—	—	—
Fairleigh Dickinson U							
Madison	12	0	2	—	—	—	—
Teaneck	8	5	6	—	—	—	—
Fisk U	8	0	2	—	—	—	—
Florida Atlantic U	2	16	1	—	—	—	—
Florida Institute of Tech	1	2	0	—	a	—	—
Florida International U	9	6	—	—	—	—	—
Florida State U	2	26	5	10	—	—	—
Florida, U of	7	39	9	13	42	17	3
Fordham U	1	9	2	—	—	—	—
Fort Lewis C	2	16	—	—	—	—	—
Franklin & Marshall C	8	8	—	—	—	—	—
Furman U	20	5	4	—	—	—	—
Geneva C	0	5	—	—	—	—	—
George Mason U	9	1	—	—	—	—	—
George Washington U	9	10	1	5	—	—	—
Georgetown U	18	0	8	8	—	—	—
Georgia Institute of Tech	12	0	4	14	100	24	9
Georgia State U	2	8	4	—	—	—	—
Georgia, U of	7	25	9	14	—	—	—
Gettysburg C	2	7	—	—	—	—	—
Glassboro State C	3	6	—	—	—	—	—
Gonzaga U	0	0	—	—	—	—	—
Goucher C	0	2	—	—	—	—	—
Grand Valley State C	0	2	—	—	—	—	—
Grinnell C	5	12	—	—	—	—	—
Gustavus Adolphus C	5	8	—	—	—	—	—
Hamilton C	1	4	—	—	—	—	—
Hamline U	3	2	—	—	—	—	—
Hampden-Sydney C	6	0	—	—	—	—	—
Hampton U	8	0	3	—	—	—	—
Hartford, U of	3	4	—	—	—	—	—
Hartwick C	0	5	—	—	—	—	—
Harvard U	—	31	18	36	—	—	—
Harvey Mudd C	10	0	—	—	—	—	—
Haverford C	2	7	—	—	—	—	—
Hawaii, U of	7	4	1	6	—	—	—
Hiram C	4	6	—	—	—	—	—
Hobart & William Smith C	2	14	—	—	—	—	—
Hofstra U	0	5	—	—	—	—	—
Hollins C	0	1	—	—	—	—	—
Holy Cross, C of The	11	11	—	—	—	—	—
Hope C	20	11	—	—	—	—	—
Houston, U of	10	2	9	9	a	—	—
Howard U	24	0	8	6	23	4	—
Humboldt State U	4	2	—	—	—	—	—
Idaho State U	3	3	0	—	—	—	—
Idaho, U of	2	3	6	3	33	9	1
Illinois Benedictine C	11	0	—	—	—	—	—
Illinois Institute of Tech	4	0	3	1	40	17	9
Illinois State U	37	0	7	—	—	—	—
Illinois, U of							
Chicago	29	21	22	13	a	—	—
Urbana-Champaign	74	35	2	35	83	15	15
Illinois Wesleyan U	1	3	—	—	—	—	—
Indiana State U	12	0	3	—	—	—	—
Indiana U	38	98	10	25	—	—	—
Indiana U of Pennsylvania	11	8	3	—	—	—	—
Indiana U at South Bend	5	1	—	—	—	—	—
Indiana U Northwest	0	6	—	—	—	—	—
Indiana U-Purdue U							
Fort Wayne	5	5	—	—	—	—	—
Indianapolis	1	39	7	—	—	—	—
Iowa State U	16	7	7	33	68	7	1
Iowa, U of	10	2	9	9	26	5	3
Ithaca C	6	0	—	—	—	—	—
Jackson State U	4	1	2	—	—	—	—
James Madison U	1	5	—	—	—	—	—
John Carroll C	4	26	1	—	—	—	—
Johns Hopkins U	8	6	6	10	16	3	8
Juniata C	3	13	—	—	—	—	—
Kalamazoo C	3	16	—	—	—	—	—
Kansas State U	6	1	3	9	23	4	2
Kansas, U of	10	22	2	8	38	8	2
Kean C of New Jersey	6	3	—	—	—	—	—
Kearney State C	2	3	—	—	—	—	—
Kent State U	14	7	1	4	—	—	—
Kentucky, U of	16	18	3	2	48	9	2
Kenyon C	4	9	—	—	—	—	—
King's C	5	3	—	—	—	—	—
Knox C	0	20	—	—	—	—	—
Lafayette C	4	9	—	—	34	—	—
Lake Forest C	3	4	—	—	—	—	—
Lamar U	4	2	5	—	23	2	2
La Salle C	2	0	—	—	—	—	—
Lawrence Institute of Tech	6	0	—	—	—	—	—
Lawrence U[c]	5	3	9	4	—	—	—
Lebanon Valley C	4	5	—	—	—	—	—
Lehigh U	22	0	13	11	33	26	11
Le Moyne C	6	0	—	—	—	—	—
Lewis & Clark C	0	7	—	—	—	—	—
Lincoln U	1	8	—	—	—	—	—
Long Island U							
Brooklyn Center	0	6	0	—	—	—	—
C. W. Post C	3	0	—	—	—	—	—
Loras C	2	1	—	—	—	—	—
Louisiana State U							
Baton Rouge	5	11	2	10	45	11	2
Shreveport	3	0	—	—	—	—	—
Louisiana Tech U	4	0	2	—	a	—	—
Louisville, U of	6	17	1	4	26	11	3
Lowell, U of	8	1	4	8	32	5	—
Loyola C	4	2	—	—	—	—	—
Loyola Marymount U	3	4	—	—	—	—	—
Loyola U							
New Orleans	1	1	—	—	—	—	—
Chicago	11	15	5	3	—	—	—
Luther C	0	3	—	—	—	—	—
Macalester C	3	3	—	—	—	—	—
Maine, U, at Orono	6	5	2	1	34	2	2
Manhattan C[d]	12	1	—	—	49	30	—
Manhattanville C	2	0	—	—	—	—	—
Mankato State U	12	7	1	—	—	—	—
Marietta C	4	0	—	—	—	—	—
Marist C	0	3	—	—	—	—	—
Marquette U	4	0	6	9	—	—	—
Marshall U	4	20	2	—	—	—	—
Maryland, U of							
College Park	19	60	12	22	a	—	—
Baltimore County	10	20	5	—	—	—	—
Massachusetts Institute of Tech	42	0	2	38	54	35	27
Massachusetts, U of	11	6	3	12	32	8	6
McNeese State U	6	0	4	—	—	—	—
Memphis State U	3	4	0	1	—	—	—
Mercer U	4	3	—	—	—	—	—
Merrimack C	1	2	—	—	—	—	—
Metropolitan State C	8	21	—	—	—	—	—
Miami U	21	32	3	9	—	—	—
Miami, U of	0	52	2	3	—	—	—
Michigan State U	18	17	10	36	50	15	4
Michigan Technological U	18	0	3	0	71	9	2
Michigan, U of							
Ann Arbor	63	0	29	28	73	6	6
Dearborn	10	5	—	—	—	—	—
Flint	1	10	—	—	—	—	—
Middle Tennessee State U	0	24	3	—	—	—	—
Middlebury C	0	9	0	—	—	—	—
Midwestern State U	1	7	—	—	—	—	—
Millersville U	1	10	—	—	—	—	—
Millsaps C	2	12	—	—	—	—	—
Minnesota, U of							
Minneapolis	36	0	6	20	98	3	18
Duluth	8	20	4	—	—	—	—
Mississippi C	3	4	—	—	—	—	—

CIRCLE 61 ON READER SERVICE CARD →

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Mississippi State U	0	0	3	3	44	3	2
Mississippi, U of	2	6	2	1	14	5	1
Missouri, U of							
Columbia	12	4	9	1	22	9	2
Kansas City	9	14	1	5	—	—	—
Rolla	12	0	5	6	110	16	3
St. Louis	12	11	6	2	—	—	—
Missouri Western State C	2	0	—	—	—	—	—
Monmouth C							
Illinois	3	3	—	—	—	—	—
New Jersey	3	0	—	—	—	—	—
Montana C of Mineral Science & Tech	3	1	2	—	—	—	—
Montana State U	2	9	3	5	49	14	2
Montana, U of	5	5	3	2	—	—	—
Montclair State C	7	12	3	—	—	—	—
Moorhead State U	3	5	—	—	—	—	—
Moravian C	2	3	—	—	—	—	—
Morehouse C[c]	4	1	6	3	—	—	—
Morgan State U	3	1	—	—	—	—	—
Mount Holyoke C	0	10	1	1	—	—	—
Mount Saint Vincent, C of[d]	0	0	—	—	—	—	—
Muhlenberg C	0	22	—	—	—	—	—
Murray State U	4	11	1	—	—	—	—
Muskingum C	2	7	—	—	—	—	—
Nebraska, U of							
Lincoln	3	13	5	11	30	12	0
Omaha	5	5	—	—	—	—	—
Nebraska Wesleyan U	6	5	—	—	—	—	—
Nevada, U of							
Las Vegas	0	8	0	—	—	—	—
Reno	2	3	2	2	—	—	—
New Hampshire, U of	10	6	7	3	a	—	—
New Jersey Institute of Tech[b]	—	—	—	—	66	14	3
New Mexico Highlands U	0	0	0	—	—	—	—
New Mexico Institute of Mining & Tech	9	0	7	—	—	—	—
New Mexico State U	7	16	4	7	30	4	1
New Mexico, U of	8	6	9	4	19	8	4
New Orleans, U of	5	8	2	3	—	—	—
New York U	5	40	19	9	—	—	—
Niagara U	0	12	—	—	—	—	—
North Alabama, U of	2	8	—	—	—	—	—
North Carolina A&T State U	4	0	5	—	—	—	—
North Carolina Central U	0	5	3	—	—	—	—
North Carolina State U	21	24	5	7	102	3	2
North Carolina, U of							
Asheville	3	1	—	—	—	—	—
Chapel Hill	40	79	9	26	—	—	—
Charlotte	2	5	2	—	—	—	—
Greensboro	5	5	3	—	—	—	—
Wilmington	8	8	—	—	—	—	—
North Dakota State U	1	20	6	5	—	—	—
North Dakota, U of	7	3	1	6	33	4	—
North Texas State U	4	5	8	7	—	—	—
Northeast Louisiana U	2	1	2	—	—	—	—
Northeastern Illinois U	2	13	5	—	—	—	—
Northeastern U	4	0	11	7	a	—	—
Northern Arizona U	3	12	0	—	—	—	—
Northern Colorado, U of	1	8	1	1	—	—	—
Northern Illinois U	10	11	3	4	—	—	—
Northern Iowa, U of	4	20	1	—	—	—	—
Northern Kentucky U	3	6	—	—	—	—	—
Northern Michigan U	3	6	0	—	—	—	—
Northwest Missouri State U	4	0	—	—	—	—	—
Northwestern State U of Louisiana	0	1	—	—	—	—	—
Northwestern U	10	15	29	21	41	40	11
Norwich U	1	0	—	—	—	—	—
Notre Dame, U of	6	9	3	8	50	11	9
Oakland U	6	3	0	—	—	—	—
Oberlin C	0	15	—	—	—	—	—
Occidental C	6	8	—	—	—	—	—
Ohio Northern U	5	5	—	—	—	—	—
Ohio State U	33	0	16	30	56	21	3
Ohio U	5	6	4	5	23	8	0
Ohio Wesleyan U	0	6	—	—	—	—	—
Oklahoma State U	3	1	3	11	26	15	4
Oklahoma, U of	9	24	10	11	39	20	2
Old Dominion U	11	7	5	—	—	—	—
Oregon State U	22	0	3	6	41	6	0
Oregon, U of	6	29	6	10	—	—	—
Pace U	4	2	—	—	—	—	—
Pacific Lutheran U	3	9	—	—	—	—	—
Pacific, U of The	1	3	2	0	—	—	—
Pennsylvania State U	6	33	10	24	165	17	9
Pennsylvania, U of	6	28	9	15	35	19	6
Philadelphia C of Pharmacy & Science	3	0	3	0	—	—	—
Philadelphia C of Textiles & Sciences	1	0	—	—	—	—	—
Pittsburg State U	4	2	3	—	—	—	—
Pittsburgh, U of	25	52	10	16	83	13	4
Polytechnic U	6	0	6	12	37	5	6
Pomona C	1	5	—	—	—	—	—
Portland State U	4	10	0	2	—	—	—
Pratt Institute[b]	—	—	—	—	a	—	—
Princeton U	21	12	20	21	17	5	10
Providence U	5	5	0	0	—	—	—
Puerto Rico, U of							
Mayaguez	21	6	3	—	63	6	—
Rio Piedras	15	43	5	1	—	—	—
Puget Sound, U of	7	4	—	—	—	—	—
Purdue U	59	30	11	32	128	18	10
Purdue U Calumet	9	2	—	—	—	—	—
Randolph-Macon Woman's C	0	4	—	—	—	—	—
Ramapo C of New Jersey	1	6	—	—	—	—	—
Redlands, U of	1	1	—	—	—	—	—
Reed C	16	0	—	—	—	—	—
Rensselaer Polytechnic Inst	25	0	26	14	51	14	9
Rhode Island, U of	7	1	2	5	39	4	1
Rhodes C	1	9	—	—	—	—	—
Rice U	3	7	20	11	20	12	9
Richmond, U of	3	14	0	0	—	—	—
Rider C	1	0	—	—	—	—	—
Ripon C	3	3	—	—	—	—	—
Roanoke C	6	1	—	—	—	—	—
Rochester Institute of Tech	5	9	10	—	—	—	—
Rochester, U of	26	0	23	19	20	15	4
Rollins C	5	1	—	—	—	—	—
Roosevelt U	5	1	7	—	—	—	—
Rose-Hulman Institute of Tech	11	0	—	—	69	6	—
Russell Sage C	1	1	—	—	—	—	—
Rutgers U							
New Brunswick	48	31	9	15	71	20	3
Camden C	1	11	—	—	—	—	—
Newark C of Arts & Sciences	4	7	4	4	—	—	—
Saginaw Valley State C	1	13	—	—	—	—	—
St. Anselm C	1	2	—	—	—	—	—
St. Catherine, C of	2	8	—	—	—	—	—
St. Cloud State U	1	9	—	—	—	—	—
St. John Fisher C	9	1	—	—	—	—	—
St. John's U	7	4	4	—	—	—	—
St. John's U/C of St. Benedict	4	11	—	—	—	—	—
St. Joseph C	2	0	6	—	—	—	—
St. Joseph's U	3	21	8	—	—	—	—
St. Lawrence U	1	15	—	—	—	—	—
St. Louis U	6	21	3	—	—	—	—
St. Mary's C	1	2	—	—	—	—	—
St. Michael's C	0	2	—	—	—	—	—
St. Olaf C	7	38	—	—	—	—	—
St. Peter's C	3	2	—	—	—	—	—
St. Thomas, C of	1	9	—	—	—	—	—
Salem State C	2	1	—	—	—	—	—
Sam Houston State U	10	0	3	—	—	—	—
San Diego State U	18	0	18	2	—	—	—
San Francisco State U	6	24	2	—	—	—	—
San Francisco, U of	4	2	2	—	—	—	—
San Jose State U	13	20	6	—	a	—	—
Sangamon State U	3	0	—	—	—	—	—
Santa Clara, U of	2	5	—	—	—	—	—
Scranton, U of	6	8	9	—	—	—	—
Seattle U	2	3	—	—	—	—	—
Seton Hall U	7	10	11	7	—	—	—
Shippensburg U	6	4	4	—	—	—	—
Siena C	2	1	—	—	—	—	—
Simmons C	1	1	—	—	—	—	—
Skidmore C	2	24	—	—	—	—	—
Smith C	8	0	0	0	—	—	—
Sonoma State U	3	22	—	—	—	—	—

← CIRCLE 61 ON READER SERVICE CARD

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
South Alabama, U of[b]	—	—	—	—	a	—	—
South Carolina, U of	4	27	5	24	27	7	0
South Dakota School of Mines & Tech	5	0	1	—	34	6	—
South Dakota State U	1	26	0	—	—	—	—
South Dakota, U of	2	9	2	—	—	—	—
South Florida, U of	16	47	1	2	28	4	1
Southeast Missouri State U	1	7	—	—	—	—	—
Southeastern Louisiana U	0	1	—	—	—	—	—
Southeastern Massachusetts U	7	5	6	—	—	—	—
Southern California, U of	14	5	2	12	28	5	3
Southern Colorado U	1	2	—	—	—	—	—
Southern Illinois U							
Carbondale	6	5	8	6	—	—	—
Edwardsville	12	6	3	—	—	—	—
Southern Methodist U	5	0	0	—	—	—	—
Southern Mississippi, U of	1	10	4	0	—	—	—
Southern Oregon State C	1	15	—	—	—	—	—
Southern U & A&M C	7	0	0	—	—	—	—
Southwest Missouri State U	0	14	—	—	—	—	—
Southwest State U	1	1	—	—	—	—	—
Southwest Texas State U	10	1	1	—	—	—	—
Southwestern Louisiana, U of	0	12	—	—	a	—	—
Southwestern Oklahoma State U	3	3	—	—	—	—	—
Stanford U	9	9	1	23	14	13	9
State U of New York							
Albany	10	9	5	5	—	—	—
Binghamton	10	27	1	10	—	—	—
Buffalo	19	9	9	17	70	15	6
Stony Brook	19	23	5	12	—	—	—
C at Brockport	3	6	—	—	—	—	—
C at Buffalo	6	8	1	—	—	—	—
C at Cortland	0	14	—	—	—	—	—
C at Fredonia	5	5	0	—	—	—	—
C at Geneseo	6	0	—	—	—	—	—
C at New Paltz	4	3	2	—	—	—	—
C at Oneonta	1	16	0	—	—	—	—
C at Oswego	21	7	3	—	—	—	—
C at Plattsburgh	7	13	2	—	—	—	—
C at Potsdam	0	15	—	—	—	—	—
Stephen F. Austin State U	4	1	0	—	—	—	—
Stetson U	4	1	—	—	—	—	—
Stevens Institute of Tech	2	4	17	1	7	11	4
Suffolk U	1	2	—	—	—	—	—
Susquehanna U	1	1	—	—	—	—	—
Swarthmore C	3	8	—	—	—	—	—
Syracuse U	10	6	0	5	18	12	1
Temple U	9	3	2	1	—	—	—
Tennessee Technological U	3	10	2	—	37	6	0
Tennessee, U of							
Knoxville	3	7	8	9	60	9	4
Martin	3	8	—	—	—	—	—
Chattanooga	12	7	—	—	—	—	—
Texas A&I U	6	1	2	—	10	4	—
Texas A&M U	10	12	9	24	122	25	3
Texas Christian U	1	25	0	4	—	—	—
Texas Southern U	15	0	10	—	—	—	—
Texas Technological U	8	11	7	7	40	12	1
Texas, U of							
Arlington	8	12	4	2	—	—	—
Austin	44	0	14	41	105	20	11
Dallas	6	0	2	1	—	—	—
El Paso	5	0	12	—	—	—	—
Texas Woman's U	1	3	1	1	—	—	—
Thiel C	2	4	—	—	—	—	—
Thomas More C	2	0	—	—	—	—	—
Toledo, U of	1	9	2	3	26	8	1
Towson State U	4	5	—	—	—	—	—
Trenton State C	8	0	—	—	—	—	—
Trinity C	4	7	0	—	—	—	—
Trinity U	1	8	—	—	—	—	—
Tri-State U[b]	—	—	—	—	a	—	—
Tufts U	0	20	1	2	28	9	2
Tulane U of Louisiana	1	14	1	6	19	3	1
Tulsa, U of	1	0	—	—	32	8	2
Tuskegee U	0	5	4	—	8	—	—
Union C	4	12	—	—	—	—	—
U.S. Air Force Academy	6	7	—	—	—	—	—
U.S. Naval Academy	10	5	—	—	—	—	—
Ursinus C	5	16	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Utah State U	9	0	3	2	—	—	—
Utah, U of	5	31	5	19	a	—	—
Valparaiso U	5	30	—	—	—	—	—
Vanderbilt U	0	32	5	8	23	7	0
Vassar C	0	8	0	—	—	—	—
Vermont, U of	12	0	2	5	—	—	—
Villanova U	15	0	6	3	21	15	—
Virginia Commonwealth U	7	18	2	6	—	—	—
Virginia Military Institute	5	0	—	—	—	—	—
Virginia Polytechnic Institute & State U	22	14	8	16	72	3	3
Virginia, U of	7	92	9	10	28	31	2
Wabash C	9	9	—	—	—	—	—
Wagner C	1	7	—	—	—	—	—
Wake Forest U	13	18	1	1	—	—	—
Washburn U of Topeka	2	1	—	—	—	—	—
Washington C	4	0	—	—	—	—	—
Washington & Jefferson C	2	18	—	—	—	—	—
Washington & Lee U	0	9	—	—	—	—	—
Washington State U	11	7	14	7	26	6	3
Washington U	0	7	12	2	42	13	3
Washington, U of	41	17	7	11	41	11	4
Wayne State U	15	30	8	15	37	18	2
Waynesburg C	4	2	—	—	—	—	—
Weber State C	6	8	—	—	—	—	—
Wellesley C	5	29	—	—	—	—	—
Wesleyan U	4	16	1	4	—	—	—
West Chester U	7	15	0	—	—	—	—
West Florida, U of	3	7	—	—	—	—	—
West Texas State U	0	4	1	—	—	—	—
West Virginia Institute of Tech[b]	—	—	—	—	20	0	—
West Virginia State C	1	7	—	—	—	—	—
West Virginia U	12	46	4	4	43	9	8
Western Illinois U	5	2	4	—	—	—	—
Western Kentucky U	3	11	7	—	—	—	—
Western Maryland C	2	5	—	—	—	—	—
Western Michigan U	7	14	5	0	—	—	—
Western New England C	2	0	—	—	—	—	—
Western Washington U	8	19	1	—	—	—	—
Westminster C	0	5	—	—	—	—	—
Wheaton C							
Illinois	2	18	—	—	—	—	—
Massachusetts	4	3	—	—	—	—	—
Wheeling C	0	2	—	—	—	—	—
Whitman C	3	7	—	—	—	—	—
Whittier C	2	6	—	—	—	—	—
Wichita State U	11	11	3	—	—	—	—
Widener U	0	0	—	—	13	2	—
Wilkes C	2	0	—	—	—	—	—
Willamette U	3	4	—	—	—	—	—
William Paterson C of N.J.	0	5	—	—	—	—	—
William & Mary, C of	24	5	5	—	—	—	—
Williams C	0	24	—	—	—	—	—
Wisconsin, U of							
Eau Claire	5	4	—	—	—	—	—
Green Bay	0	12	—	—	—	—	—
La Crosse	5	13	—	—	—	—	—
Madison	17	17	14	44	99	6	12
Milwaukee	4	19	11	7	—	—	—
Oshkosh	5	5	—	—	—	—	—
Parkside	5	1	—	—	—	—	—
Platteville	1	1	—	—	—	—	—
River Falls	3	8	—	—	—	—	—
Stevens Point	8	4	—	—	—	—	—
Superior	3	2	—	—	—	—	—
Wittenberg U	1	5	—	—	—	—	—
Wooster, C of	0	23	—	—	—	—	—
Worcester Polytechnic Institute	10	4	0	1	41	8	1
Wright State U	21	11	10	—	—	—	—
Wyoming, U of	0	1	1	4	14	13	2
Xavier U	4	8	2	—	—	—	—
Xavier U of Louisiana	1	31	—	—	—	—	—
Yale U	12	0	24	19	a	—	—
Youngstown State U	13	29	10	—	a	—	—
TOTALS	**3892**	**5403**	**1620**	**1885**	**5229**	**1244**	**460**

Note: For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column. a Data not submitted. b Listed on basis of accreditation by AIChE-ABET. c Master's and Ph.D. degrees given by the Institute of Paper Chemistry. d The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with all instruction in chemistry located at Manhattan College. e Master's and Ph.D. degrees given by Atlanta University.

Indiana remains top producer of chemists

Indiana University graduated more B.S. chemists (136) in the 1985–86 academic year than any other school in the country, as it did in the previous academic year. The University of North Carolina, Chapel Hill, remained in second place with 119. The University of Illinois, Champaign-Urbana, retained the third spot with 109.

The biggest producer of new Ph.D. chemists in 1985–86 was the University of California, Berkeley, as it had been in 1984–85, with 69. The University of Wisconsin, Madison, moved up from fourth the previous year to second with 44 graduates. And the University of Texas, Austin, climbed from 10th to take third place with 41.

These are some of the data gleaned by C&EN from the latest annual report of ACS's Committee on Professional Training (see page 59). This committee is charged with setting standards for undergraduate chemistry education and monitoring them. It also collects data annually from departments with programs it approves on the number of new chemistry graduates at all levels.

According to the new report, the University of Illinois, Urbana-Champaign, was the largest producer in 1985–86 of new chemists with undergraduate degrees certified by ACS. The University of California, San Diego, the 1984–85 leader, dropped to sixth. Certified graduates are immediately eligible for ACS membership.

The distinction of being the largest producer of new Ph.D. chemists has been shared for the past 13 years exclusively by the University of California, Berkeley, five times, including last year, and Illinois, Urbana-Champaign, eight times. In 1985–86, however, the Illinois school slipped to seventh.

Cornell University was the largest producer of M.S. chemists with 36 in 1985–86. Second was the University of Michigan, Ann Arbor, with 29. In 1984–85 these two schools shared the lead in this category, each with 31 graduates.

Michael Heylin, Washington

These schools had most chemistry graduates, 1985–86

Total bachelor graduates

1. Indiana U	136
2. U of North Carolina, Chapel Hill	119
3. U of Illinois, Urbana-Champaign	109
4. U of California, Los Angeles	100
5. U of Virginia	99
6. Purdue U	89
7. U of Maryland, College Park	79
7. Rutgers U	79
9. U of Pittsburgh	77
10. U of California, Berkeley	71
11. U of California, Irvine	66
12. U of Michigan, Ann Arbor	63
12. U of South Florida	63
14. Cornell U	59
14. Duke U	59
16. U of Puerto Rico, Rio Piedras	58
16. U of Washington	58
16. West Virginia U	58
19. U of Arizona	55
19. U of Delaware	55
21. Miami U	53
22. U of Colorado, Boulder	52
22. U of Miami	52
24. U of Illinois, Chicago	50
25. U of California, San Diego	46
25. U of Florida	46

Certified bachelor graduates

1. U of Illinois, Urbana-Champaign	74
2. U of California, Berkeley	70
3. U of Michigan	63
4. Purdue U	59
5. Rutgers U	48
6. U of California, San Diego	46
7. U of Texas, Austin	44
8. Massachusetts Inst of Tech	42
9. U of Delaware	41
9. U of Washington	41
11. U of North Carolina, Chapel Hill	40
12. Indiana U	38
13. Illinois State U	37
14. U of Minnesota	36
15. Ohio State U	33
16. U of California, Davis	30
17. U of Illinois, Chicago	29
18. U of California, Los Angeles	27
19. U of Connecticut	26
19. U of Rochester	26
21. U of Arizona	25
21. U of Pittsburgh	25
21. Rensselaer Polytechnic Inst	25
24. U of California, Santa Barbara	24
24. Cornell U	24
24. Howard U	24
24. C of William & Mary	24

Master's graduates

1. Cornell U	36
2. U of Michigan	29
3. Northwestern U	29
4. Rensselaer Polytechnic Inst	26
5. Yale U	24
6. U of Rochester	23
7. U of Illinois, Chicago	22
8. Columbia U	21
9. U of Cincinnati	20
9. Princeton U	20
9. Rice U	20
12. New York U	19
13. Harvard U	18
13. San Diego State U	18
15. Stevens Inst of Tech	17
16. Ohio State U	16
17. U of Texas, Austin	14
17. Washington State U	14
17. U of Wisconsin, Madison	14
20. Lehigh U	13
21. U of Arizona	12
21. U of California, Los Angeles	12
21. U of California, San Diego	12
21. Case Western Reserve U	12
21. U of Maryland, College Park	12
21. U of Texas, El Paso	12
21. Washington U	12

Doctoral graduates

1. U of California, Berkeley	69
2. U of Wisconsin, Madison	44
3. U of Texas, Austin	41
4. Massachusetts Inst of Tech	38
5. Harvard U	36
5. Michigan State U	36
7. U of Illinois, Urbana-Champaign	35
8. Iowa State U	33
9. Purdue U	32
10. Cornell U	30
10. Ohio State U	30
12. California Inst of Tech	29
12. U of California, Los Angeles	29
14. U of Michigan, Ann Arbor	28
15. U of North Carolina, Chapel Hill	26
16. U of California, San Diego	25
16. Indiana U	25
18. Pennsylvania State U	24
18. U of South Carolina	24
18. Texas A&M U	24
21. Stanford U	23
22. U of California, Santa Barbara	22
22. Case Western Reserve	22
22. U of Maryland, College Park	22
25. Northwestern U	21
25. Princeton U	21